TECHNICAL MEMORANDUMS

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 417

DRAG MEASUREMENTS OF TWO THIN WING SECTIONS AT DIFFERENT INDEX VALUES

By J. Ackeret

From Report III of the Göttingen Aerodynamic Institute, 1927

Washington
June, 1927

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In Part I, Chapter 1, of this report, it is stated that the index value 6000, as found in normal tests of wing sections with a 20 cm (7.87 in.) chord, falls in the same region where the transition of laminar to turbulent flow takes place on thin flat plates. It is to be expected that slightly cambered, thin wing sections will behave similarly. The following tests of two such wing sections were made for the purpose of verifying this supposition.

The wing sections are shown in Fig. 1. The lower sides of both are straight nearly to the leading edge. Their chords are about 40 cm (15.75 in.) and their spans 120 cm (47.24 in.). Only small lifts were tested, so that the suspension wires could be as small as possible, in order to reduce their drag.

In other respects the measurements were made just the same as with normal surfaces. The computed induced drag was deduced from the total measured drag. The rest of the drag was referred to the whole wing area, for comparison with the flat measurements, and the corresponding coefficient was designated by c_f

* "Profilwiderstände zweier dünner Profile bei verschiedenen Kennwerten." From "Ergebnisse der Aerodynamischen Versuchsanstalt zu Göttingen." Report III, 1927, pp. 87-91.

(Tables I-X). In Figs. 2-3, the c_f values are plotted logarithmically against the Reynolds Number $R = \frac{vt}{\nu}$, in which t = the chord. For comparison with the flat measurements (See Fig. 2, p. 5 of this report), the straight lines I and III (resp. turbulent and laminar flow) and the transition curve II are also introduced.

As always in the transition field, the measuring points are quite hard to reproduce, but still no parallel flow is recognizable with the flat measurements at small angles of attack, especially with the thinner section. From the experiments, the conclusion can be drawn that thin sections should not be tested at Reynolds Numbers smaller than $R = 10^6$.

TABLE I.

Wing Section 1.

a) Angle of attack $\alpha = -2.1°$.

Pressure q kg/m^2	Velocity v m/s	$R = \frac{vt}{\nu}$	Coef. of friction c_f	100 c_a	100 c_w	(L/D)
6.26	10.2	2.87×10^5	0.00370	10.1	0.85	11.9
14.06	15.3	4.31×10^5	0.00365	9.6	0.83	11.5
25.7	20.7	5.83×10^5	0.00355	8.7	0.79	11.0
39.3	25.6	7.20×10^5	0.00360	8.2	0.79	10.5
56.3	30.7	8.63×10^5	0.00355	7.8	0.77	10.2
76.5	35.7	1.01×10^6	0.00350	7.0	0.75	9.3
100.0	40.8	1.15×10^6	0.00345	6.3	0.73	8.7
126.6	46.0	1.30×10^6	0.00340	6.0	0.72	8.3
Repetition						
6.22	10.2	2.87×10^5	0.00355	10.7	0.83	12.8
13.85	15.2	4.27×10^5	0.00370	9.7	0.84	12.3
25.0	20.4	5.73×10^5	0.00370	9.1	0.83	10.9
56.1	30.6	8.61×10^5	0.00350	7.7	0.76	10.1
99.9	40.8	1.15×10^6	0.00330	6.3	0.70	9.0

Table II

b) Angle of attack $\alpha = -0.2°$.

Pressure q kg/m^2	Velocity v m/s	$R = \frac{vt}{\nu}$	Coef. of friction c_f	100 c_a	100 c_w	(L/D)
6.32	10.28	2.89×10^5	0.00328	20.9	1.12	18.6
14.12	15.38	4.32×10^5	0.00265	19.4	0.93	20.9
39.0	25.55	7.18×10^5	0.00298	17.7	0.93	19.0
56.2	30.6	8.60×10^5	0.00318	17.4	0.96	18.2
77.0	35.9	1.01×10^6	0.00315	16.8	0.93	18.1
103.1	41.5	1.17×10^6	0.00322	16.1	0.92	17.4
129.0	46.4	1.30×10^6	0.00320	15.6	0.90	17.3
Repetition						
6.19	10.17	2.86×10^5	0.00331	20.3	1.10	18.5
25.15	20.55	5.78×10^5	0.00287	18.3	0.93	19.7
39.0	25.55	7.19×10^5	0.00285	17.6	0.90	19.6
56.2	30.6	8.60×10^5	0.00323	17.2	0.96	18.0
100.3	40.9	1.15×10^6	0.00318	16.3	0.92	17.8
126.7	45.9	1.29×10^6	0.00317	15.8	0.90	17.6

Table III.

c) Angle of attack $\alpha = 1.8^\circ$.

Pressure q kg/m²	Velocity v m/s	$R = \frac{vt}{\nu}$	Coef. of friction c_f	100 c_a	100 c_w	(L/D)
6.31	10.27	2.88×10^5	0.00430	28.6	1.73	16.6
14.1	15.35	4.31×10^5	0.00348	28.5	1.56	18.3
24.9	20.4	5.73×10^5	0.00328	28.5	1.52	18.7
39.2	25.6	7.20×10^5	0.00330	27.9	1.49	18.8
56.3	30.7	8.63×10^5	0.00312	27.5	1.43	19.2
76.6	35.8	1.01×10^6	0.00298	27.3	1.39	19.7
100.1	40.9	1.15×10^6	0.00303	26.6	1.36	19.6
126.6	46.0	1.29×10^6	0.00292	26.3	1.32	19.8
		Repetition				
14.1	15.35	4.31×10^5	0.00358	28.5	1.57	18.2
39.1	25.6	7.20×10^5	0.00318	28.0	1.47	19.1
76.6	35.8	1.01×10^6	0.00290	27.4	1.38	19.8

Table IV.

d) Angle of attack $\alpha = 3.6^\circ$.

Pressure q kg/m²	Velocity v m/s	$R = \frac{vt}{\nu}$	Coef. of friction c_f	100 c_a	100 c_w	(L/D)
6.31	10.3	2.90×10^5	0.00475	41.3	2.77	14.9
14.2	15.4	4.33×10^5	0.00400	40.5	2.55	15.9
25.2	20.5	5.77×10^5	0.00375	39.9	2.45	16.2
39.3	25.7	7.21×10^5	0.00385	39.4	2.43	16.2
56.5	30.7	8.62×10^5	0.00375	39.2	2.39	16.4
76.8	35.9	1.01×10^6	0.00365	39.0	2.35	16.5
100.3	41.0	1.15×10^6	0.00355	38.5	2.29	16.7
		Repetition				
6.31	10.3	2.89×10^5	0.00405	40.7	2.57	15.9
25.1	20.5	5.76×10^5	0.00385	39.8	2.46	16.2
56.6	30.8	8.65×10^5	0.00370	39.1	2.37	16.5

Table V.

e) Angle of attack $\alpha = 5.6^\circ$

Pressure q kg/m^2	Velocity v m/s	$R = \frac{vt}{\nu}$	Coef. of friction c_f	100 c_a	100 c_w	(L/D)
6.22	10.2	2.87×10^5	0.00480	51.0	3.73	13.7
13.92	15.3	4.31×10^5	0.00580	50.8	3.90	13.0
25.1	20.5	5.77×10^5	0.00515	50.2	3.71	13.5
39.1	25.6	7.20×10^5	0.00525	49.7	3.68	13.5
56.6	30.8	8.66×10^5	0.00505	49.5	3.62	13.7
76.9	35.9	1.01×10^6	0.00485	49.5	3.58	13.8
100.0	41.0	1.15×10^6	0.00525	48.6	3.57	13.6

Repetition

14.35	15.5	4.36×10^5	0.00585	50.7	3.91	13.0
39.2	25.7	7.23×10^5	0.00495	50.4	3.69	13.6
56.1	30.7	8.64×10^5	0.00510	49.6	3.64	13.6

Table VI.

Wing Section 2.

a) Angle of attack $\alpha = -2.15^\circ$.

Pressure q kg/m^2	Velocity v m/s	$R = \frac{vt}{\nu}$	Coef. of friction c_f	100 c_a	100 c_w	(L/D)
6.15	10.02	2.80×10^5	0.00348	-1.10	0.698	-1.58
8.23	11.60	3.25×10^5	0.00407	-1.33	0.815	-1.63
16.0	16.15	4.52×10^5	0.00404	-1.46	0.809	-1.81
26.9	20.9	5.85×10^5	0.00394	-1.98	0.791	-2.50
41.1	25.9	7.25×10^5	0.00392	-2.31	0.791	-2.92
58.3	30.9	8.65×10^5	0.00384	-2.76	0.775	-3.56
78.6	35.8	1.00×10^6	0.00369	-2.88	0.747	-3.86
102.2	40.8	1.14×10^6	0.00350	-3.15	0.711	-4.43
129.0	45.8	1.28×10^6	0.00358	-3.45	0.728	-4.73

Repetition

6.15	10.02	2.81×10^5	0.00312	-1.35	0.626	-2.16
8.29	11.63	3.26×10^5	0.00390	-1.38	0.781	-1.77

Table VII.

b) Angle of attack $\alpha = -0.2^{\circ}$.

Pressure q kg/m²	Velocity v m/s	$R = \frac{vt}{\nu}$	Coef. of friction c_f	100 c_a	100 c_w	(L/D)
5.98	9.88	2.77×10^5	0.00242	10.1	0.595	17.0
8.20	11.58	3.24×10^5	0.00236	9.80	0.573	17.1
15.95	16.15	4.52×10^5	0.00250	9.79	0.601	16.3
27.0	21.0	5.88×10^5	0.00237	9.45	0.564	16.7
40.9	25.8	7.22×10^5	0.00233	9.14	0.555	16.5
58.2	30.9	8.65×10^5	0.00254	9.08	0.597	15.2
78.5	35.8	1.00×10^6	0.00273	8.67	0.626	13.9
101.9	40.8	1.14×10^6	0.00287	8.40	0.664	12.6
128.4	45.8	1.28×10^6	0.00298	8.11	0.665	12.2
Repetition						
8.29	11.64	3.26×10^5	0.00233	9.54	0.555	17.2
41.0	25.9	7.25×10^5	0.00235	9.15	0.559	16.2
78.5	35.8	1.00×10^6	0.00270	8.80	0.621	14.1

Table VIII.

c) Angle of attack $\alpha = 1.9^{\circ}$.

Pressure q kg/m²	Velocity v m/s	$R = \frac{vt}{\nu}$	Coef. of friction c_f	100 c_a	100 c_w	(L/D)
6.13	10.0	2.80×10^5	0.00262	20.5	0.97	21.2
8.25	11.6	3.25×10^5	0.00284	20.4	1.01	20.6
16.1	16.2	4.54×10^5	0.00301	19.9	1.02	19.6
27.0	21.0	5.88×10^5	0.00315	19.5	1.03	19.0
41.1	25.9	7.25×10^5	0.00327	19.1	1.04	18.5
58.4	30.9	8.65×10^5	0.00334	19.0	1.05	18.0
78.5	35.8	1.00×10^6	0.00343	18.8	1.06	17.8
102.0	40.8	1.14×10^6	0.00323	18.8	1.02	18.5
128.4	45.8	1.28×10^6	0.00317	18.6	1.00	18.5
Repetition						
8.36	11.68	3.27×10^5	0.00283	20.2	1.00	20.2
41.25	25.9	7.25×10^5	0.00321	18.9	1.02	18.6
58.5	30.9	8.65×10^5	0.00336	18.8	1.05	18.0
78.5	35.8	1.00×10^6	0.00326	18.9	1.03	18.3

Table IX.

d) Angle of attack $\alpha = 3.9^\circ$.

Pressure q kg/m²	Velocity v m/s	$R = \frac{vt}{\nu}$	Coef. of friction c_f	100 c_a	100 c_w	(L/D)
6.18	10.02	2.81×10^5	0.00485	31.2	2.00	15.5
8.26	11.60	3.25×10^5	0.00480	30.5	2.04	15.7
16.0	16.15	4.53×10^5	0.00495	30.6	1.98	15.4
26.9	20.9	5.86×10^5	0.00457	30.4	1.89	16.1
40.8	25.8	7.23×10^5	0.00452	30.0	1.86	16.0
58.1	30.8	8.63×10^5	0.00440	29.7	1.82	16.3
78.2	35.7	1.00×10^6	0.00435	29.8	1.81	16.5
101.5	40.7	1.14×10^6	0.00410	29.7	1.78	16.9
128.0	45.7	1.28×10^6	0.00380	29.4	1.68	17.5
		Repetition				
8.4	11.7	3.28×10^5	0.00530	30.3	2.03	14.9
41.0	25.8	7.23×10^5	0.00485	29.6	1.89	15.7
78.3	35.7	1.00×10^6	0.00435	29.6	1.80	16.4

Table X.

e) Angle of attack $\alpha = 5.9^\circ$.

Pressure q kg/m²	Velocity v m/s	$R = \frac{vt}{\nu}$	Coef. of friction c_f	100 c_a	100 c_w	(L/D)
6.21	10.04	2.81×10^5	0.0083	41.2	3.46	11.9
8.22	11.55	3.23×10^5	0.0080	41.2	3.40	12.1
16.09	16.15	4.52×10^5	0.0075	41.0	3.28	12.5
27.0	20.93	5.86×10^5	0.0075	40.4	3.23	12.5
41.0	25.8	7.22×10^5	0.0072	40.3	3.17	12.7
58.3	30.8	8.61×10^5	0.0072	40.1	3.15	12.7
78.5	35.7	1.00×10^6	0.0070	40.2	3.10	13.0
102.0	40.7	1.14×10^6	0.0068	40.2	3.08	13.0
		Repetition				
8.35	11.65	3.26×10^5	0.0078	40.8	3.32	12.3
41.1	25.8	7.22×10^5	0.0073	40.2	3.17	12.7
78.5	35.7	1.00×10^6	0.0069	40.3	3.10	13.0

Translation by Dwight M. Miner,
National Advisory Committee for Aeronautics.

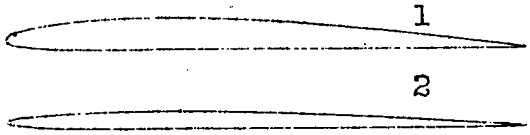

Fig.1

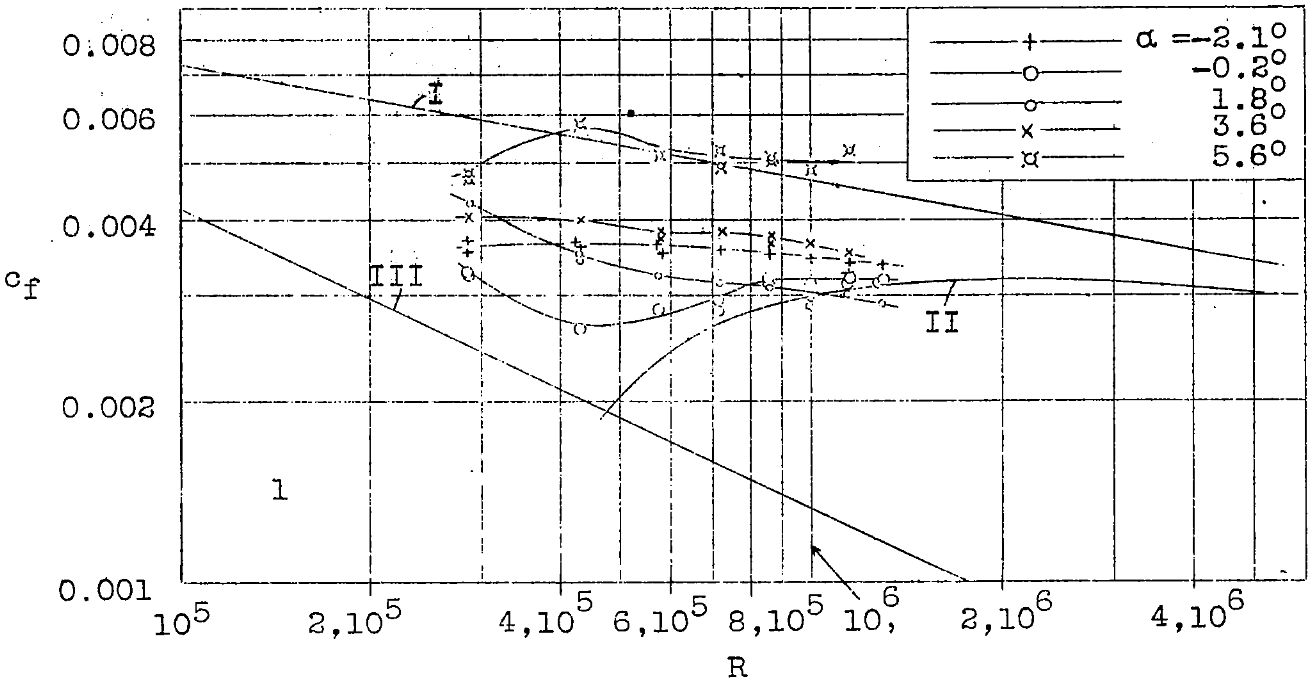

Fig.2

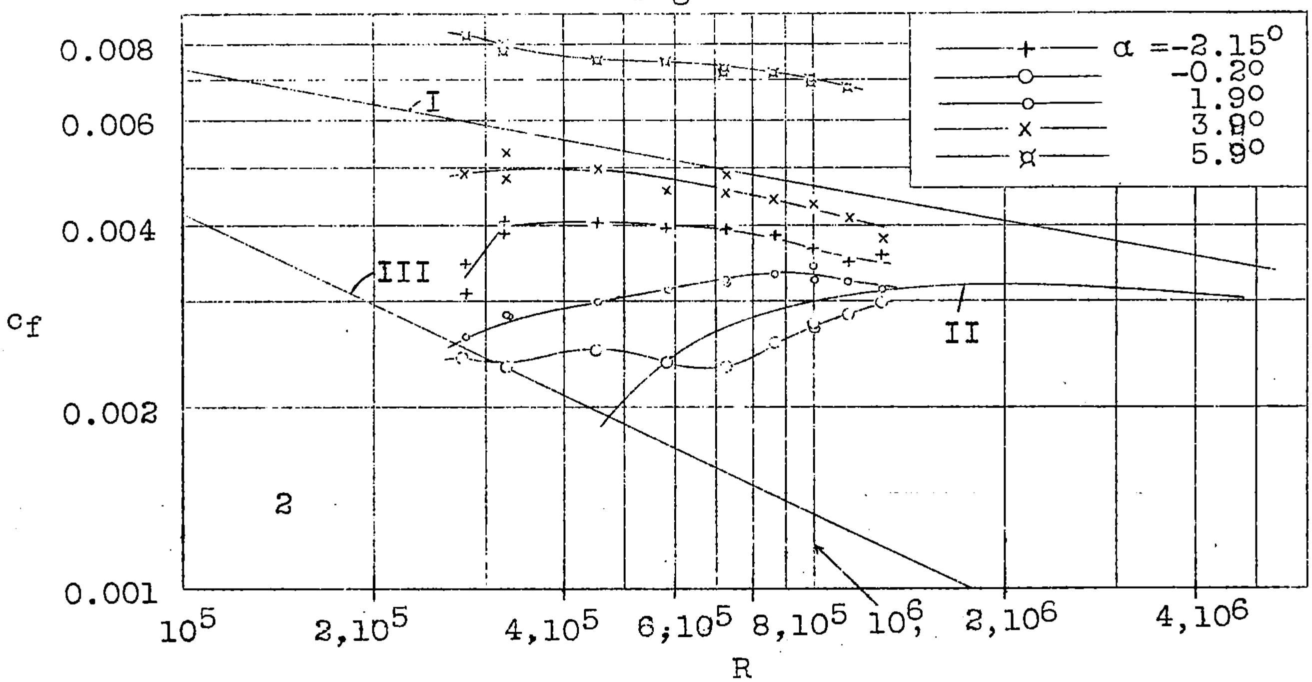

Fig.3